viii. System Components

Condensed specifications for cryogenic system related components in RHIC are given below. These specifications indicate the conceptual boundaries of performance, physically and thermally, for each component.

Inlet Recooler

The Inlet Recooler is a heat exchanger assembly located in a valve box. By means of this heat exchanger helium gas, which is about to enter the magnet string at one end (Dipole D0) of a sextant is cooled to a temperature close to the temperature of the boiling liquid helium bath provided on one side of the heat exchanger. The performance required for this heat exchanger is predicated on the analysis of Table 3-6 where this recooler is identified as Element No. BI12-RCX, RECOOLER1*FEED. RHIC Spec. No. 015, *Specification for the Design and Fabrication of a 225 Watt Recooler* is the controlling document for this piece of equipment. The performance requirements from this specification are excerpted below.

1. The recooler shall have sufficient heat exchanger surface to permit the removal of 225 W of heat from the magnet coolant stream and transfer it to a bath of boiling helium. The process diagram is shown in Fig. 3-5. The required process point conditions dictated by the RHIC operating conditions are:

Point	Pressure (bar)	Temperature (K)	Flow Rate (g/sec)
1	4.5	4.825	100
2	See para. 4, below	4.28	100
3	1.024	4.25	--
4	4.22	4.30	As required
5	1.023	Covered elsewhere	As required

2. The sum of the heat flux to the two helium streams shown in Fig. 3-5 from all sources by conduction, convection and/or radiation shall not exceed 5 W.
3. The heat flux to the heat shield circuit shall not exceed 15 W.
4. The total pressure drop in the Magnet Coolant circuit shall not exceed 0.005 bar from inlet to outlet port with fluid conditions as shown in paragraph 1. This is to include allowance for the inlet filter losses and velocity head losses due to direction change as well as frictional losses.

5. Maximum pressure drop from process point 3 to process point 5 including the phase separator shall be less than 0.001 bar.

Quad Recooler

The Quad Recooler is a heat exchanger assembly which has been designed to fit with its piping into an arc quadrupole magnet cryostat (Dwg. No. 12075000). Five of these heat exchangers are located in each sextant as indicated in Table 3-6. The first is located at Q6 where helium enters the regular arc magnets. The next four are located at even thermal intervals. The last is located at Q6 where helium exits from the regular arc magnets. By means of this heat exchanger helium gas, which passes through the magnet string is cooled periodically to a temperature close to the temperature of the boiling liquid helium bath provided on one side of the heat exchanger. The performance required for this heat exchanger is predicated on the analysis of Table 3-6 where this recooler is identified as

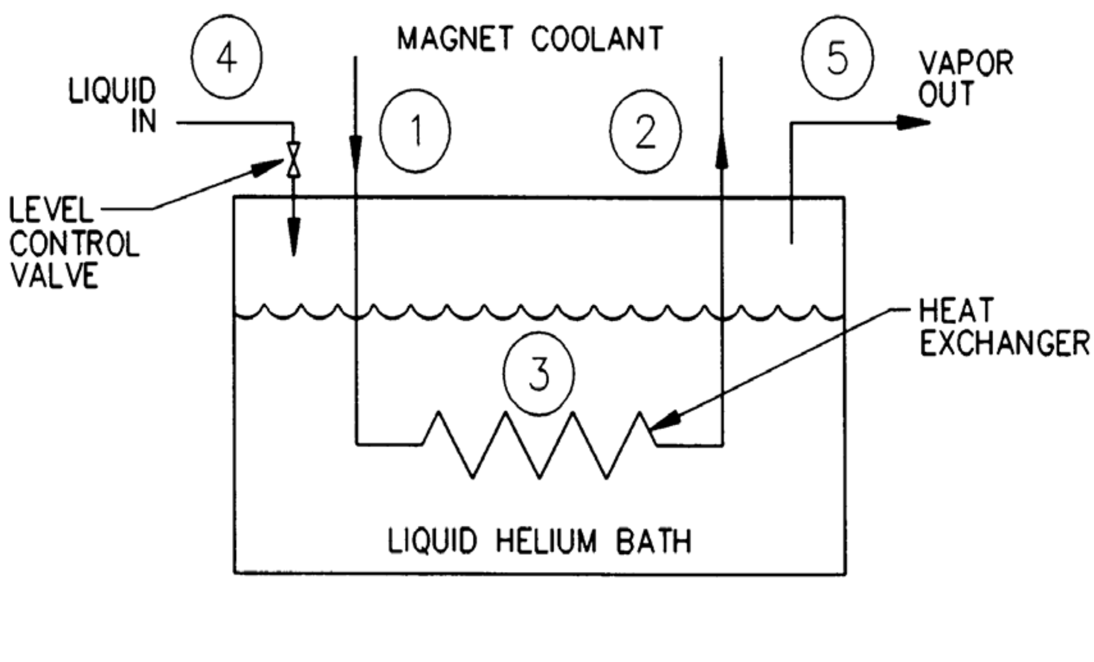

Fig. 3-5. Recooler process schematic.

Element Nos. BI12-RC6, BI12-RC14, BI12-RC21, BI1-RC14 and BI1-RC6. The recooler assembly drawing number is 34015000. The performance requirements are given below.

1. The recooler shall have sufficient heat exchanger surface to permit the removal of 50 W of heat from the magnet coolant stream and transfer it to a bath of boiling helium. The process diagram is shown in Fig. 3-5. The required process point conditions dictated by the RHIC operating conditions are:

Point	Pressure (bar)	Temperature (K)	Flow Rate (g/sec)
1	4.5	4.50	100
2	See para. 4, below	4.28	100
3	1.024	4.25	--
4	4.22	4.30	As required
5	1.023	Covered elsewhere	As required

2. The sum of the heat flux to the two helium streams shown in Fig. 3-5 from all sources by conduction, convection and/or radiation shall not exceed 2 W.
3. The recooler will be located within the 55 K heat shield of the quad cryostat.
4. The total pressure drop (process point 1 to 2) in the Magnet Coolant circuit shall not exceed 0.007 bar from inlet to outlet port with fluid conditions as shown in paragraph 1. This is to include allowance for the inlet filter losses and velocity head losses due to direction change as well as frictional losses.
5. Maximum pressure drop from process point 3 to process point 5 including the phase separator shall be less than 0.001 bar.

Circulating Compressors

A circulating compressor in each ring will be used to sustain the closed loop flow as shown in Fig. 3-2. These compressors are located at the 6 o'clock valve boxes and have the operating characteristics as shown below.

Required Operating Conditions:

	Condition 1	Condition 2
Fluid:	Helium	Helium
Flow Rate:	100 g/s	150 g/s
Inlet Pressure:	4.75 bar	4.50 bar
Outlet Pressure:	5.00 bar	5.00 bar
Inlet Temperature:	4.5 K	4.5 K
Adiabatic Efficiency:	50%	50%

Magnet Power Lead Pot

It is necessary to carry the electric power for the magnets through conductors which pass from ambient conditions (300 K) to the magnets. The lead pot at one end of each sextant must have penetrations for a minimum number of power leads as shown in Table 3-5. The lead pot is designed to share the vacuum tank of the valve box.

Cross-Insertion Vacuum Jacketed Transfer Lines

Piping is required to carry the cryogenic system helium wherever there are long gaps in the magnets in the ring, e.g., across the experimental areas and between magnets Q3 and Q4, and, at 6 o'clock only, between magnets Q7 and Q8 and magnets Q9 and D9. In all areas it is required that the superconducting buswork be carried along with the magnet coolant flow.

All the piping for a ring is carried in a common vacuum jacket with a heat shield. Pipes inside this jacket carry the helium for the following:

Magnet coolant, with leads
Supply Header
Return Header
Utility Header
Heat Shield (55 K)

This connecting piping also contains all the isolation and diverting valves required to meet the RHIC operating scenarios. Groups of these valves have been gathered into a single valve box located between each pair of sextants. These valves are shown on Drawing No. 3A995006, Overall system Block Diagram, 3-6. The isolation valves are sized at 2 inch and the diverting (block and bleed) valves are 1.5 inch. At each place on the drawing where a "B" designates a block and bleed location, there are actually three valves. These valves are arranged so that two valves are in series to block the flow and a third (smaller) valve is between them which can be used to bleed off pressure in case either of the other two valves leak. This will prevent undetected leaks.

Refrigerator to Ring Vacuum Jacketed Transfer Lines

Five pipes will connect the refrigerator to the ring. Vacuum jacketed piping transports 4.5 K helium from the refrigerator to the tunnel where it feeds into the Supply Headers for the two rings. Helium at 40 K, 15 bar is sent from the refrigerator to the Heat Shield Header.

The cold (4.5 K) helium gas which returns from the recoolers through the Return Headers will be collected and transported to the refrigerator low pressure return. In addition the Heat Shield Headers (70 K, 9 bar) combine and return to the refrigerator where it passes through an expander before joining the low-pressure return stream. Finally a cooldown return line is used during accelerator cooldown as well as during unusual operating scenarios, such as single sextant warmup.

These lines are located in a single 24 inch vacuum jacket. This line connects the refrigerator building to the two valve boxes at 6 o'clock. At the tunnel end of the line, connections will be made to the ring headers which also enter the 6 o'clock valve boxes.

Helium Vent System

A 6-inch vent stack and appropriate piping for each of the rings is provided to vent helium to the atmosphere near the end of each sextant. The stack is located at the service buildings which house the valve boxes. Relief and vent valves for the equipment in the ring are manifolded to this stack. These valves are located at the valve box. The exception to this rule includes the Magnet Circuit relief valve in each ring of every sector. These valves are located between Q6 and Q14. Their location was chosen to minimize pressure drop in the flow path to the relief valves induced by the 50 W recoolers during extreme venting conditions. These relief valves are piped to vent to the outside world.

The relief valve sizes and locations have been chosen so that the system complies with Section VIII of the ASME Pressure Vessel Code. For details, see Tech Note AD/RHIC/RD-64, "Pressure Relief for RHIC Cryogenic System," by K. C. Wu, December 1993. The size of the piping and the valves are based on studies of the magnet system venting rates during a loss of vacuum fault condition. This results in more stringent venting requirements than magnet quench scenarios. This system is designed for large temperature excursions because of the extremely cold gas which will be vented.

Ambient Ring Piping

A Warm Helium Header is provided to return lead flow helium gas to compressor suction. The main flow in this header will be the gas, which exits from the gas-cooled magnet power leads. Small relief valves will also be connected to this header. This header is continuous around the tunnel and is located overhead. During some lead fault conditions, etc., this line may be exposed to cold gas. Pipe supports and thermal expansion compensation are designed with this in mind.

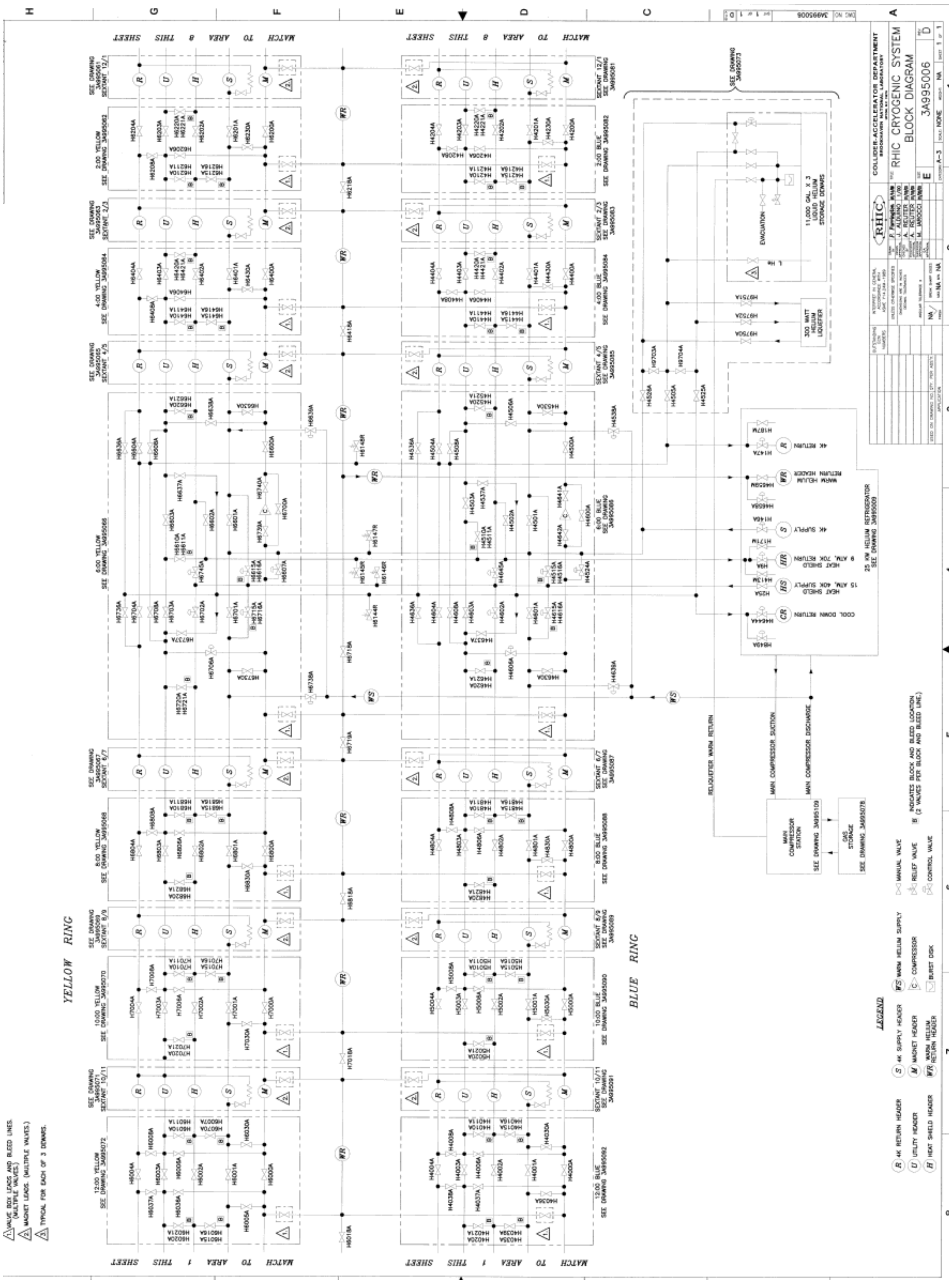

Fig.3-6. Overall System Block Diagram

80K Cooler and Reliquefier Refrigerator

A liquid nitrogen based refrigeration system has been installed near the 6 o'clock beam crossing region. Its primary purpose is to maintain the magnets and heat shield of the accelerator between 80 and 100K during shutdown periods, thus eliminating any stresses associated with thermal cycling. In this mode, Helium is cooled by heat exchange with boiling liquid Nitrogen then forced through the magnet and heat shield lines using three circulating pumps installed in the 80K Cooler cryostat.

The Cooler also has the ability to cool the accelerator from room temperature to 80K. Here, Helium from one of several compressors located throughout the RHIC cryogenic facility is refrigerated to liquid Nitrogen temperatures via pool boiling heat exchangers located in the Cooler, then routed through the ring magnets and heat shield via connections at the 6 o'clock valve box. The cooler has been integrated into the RHIC cryogenic system so as to allow the cooldown and maintenance of the accelerator to be completely independent of the main refrigerator and compressor operations. This allows for maintenance work and scrubbing of the RHIC main refrigerator and compressors while the 80K Cooler is in operations.

A 220 Watt Refrigerator has been installed in the 6 o'clock service building. It is designed to maintain liquid level in the three helium storage Dewars while the main refrigerator is not operating. As with the 80K Cooler this system runs entirely independent of the main refrigerator and compressors. Figure 3-6 describes the integration of the 80K Cooler and Reliquefier into the RHIC cryogenic system.

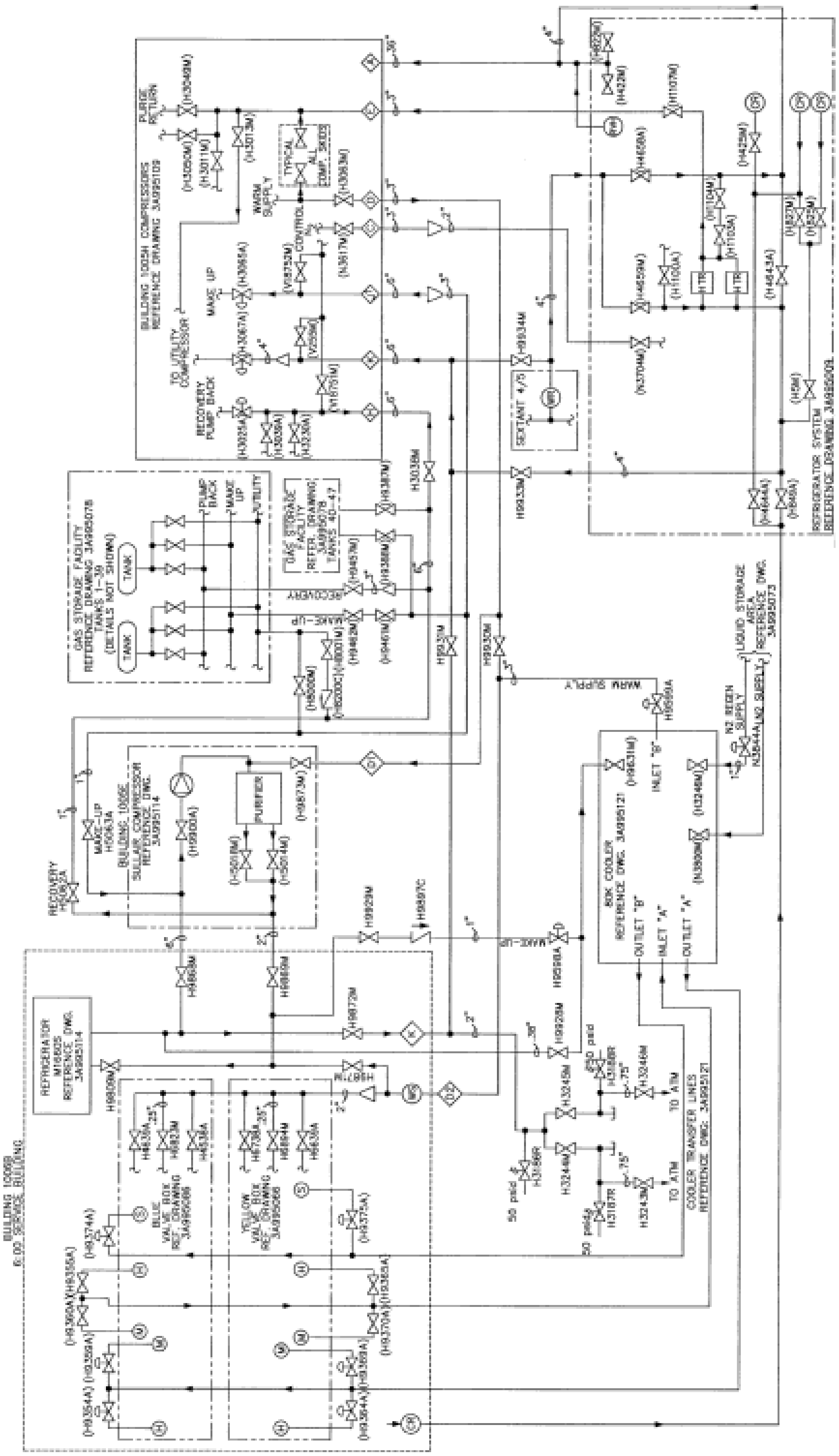

Fig 3-6: Reliquefier and 80K Cooler integration into RHIC cryogenic system